BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Power Margins for the LM-MSFN (85') Communications Link at Lunar Range Case 320

DATE: September 23, 1968

FROM: N. W. Schroeder

ABSTRACT

The expected communications capability for the LM operating at lunar range with an 85' MSFN station is evaluated for the case of a LM configured without an erectable antenna. The results which are presented show that positive margins are (in the worst case) expected for the Phase Modulated (PM) modes provided that 20 watts are transmitted from the LM steerable antenna. The results further show that negative margins are expected for all the LM Frequency Modulated (FM) television modes (in the worst case). For the back up modes using the omni antenna, positive margins are expected provided that 20 watts are transmitted from the LM and each service (back up voice, 1.6 kbps TLM, or ranging) is transmitted separately. It is expected that in spite of the negative margins of the LM-FM modes, these modes will provide usable data (the negative margins are expected to be least detrimental to TV). However, the EVA biomed back pack data will probably be lost.

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MEMORANDUM FOR FILE

The performance of the communications link between the LM and the MSFN has been evaluated to determine the communications functions that can be maintained without deploying on the lunar surface the erectable antenna carried by the LM. The antenna systems considered in this analysis include the steerable and omnidirectional antennas on the LM and only those stations of the MSFN equipped with 85-foot diameter antennas. The results that have been obtained are summarized below and are presented in Table I. Further details and the threshold criteria used in this analysis are contained in the appendix. The results presented in this memorandum represent an updating of the results in Reference 1.

The quality factor or power margin (M_p) which has been used in this evaluation is defined as the amount by which the total received signal power exceeds that which is required for the circuit margin of the selected service to equal zero. The power margins which are presented in this memorandum; therefore, represent directly the magnitude (in decibels) that the "transmitter power - antenna gain" combination may be allowed to degrade (if $M_p>0$) or the magnitude (in decibels) that this combination must be improved (if $M_p<0$) for that communication capability to exist.

The following is a summary of the major results:

1. The up-link margins are positive if 10 KW is transmitted by the MSFN station (85') to either the LM steerable or LM omni antenna; however, it is noted that the power margin of the up-voice and up-data channels using the LM omni antenna is only 0.8 dB in the worst case (full PM up-link mode and worst case parameters).

2. The down-link (using the LM steerable antenna, the MSFN (85') antenna, and a vehicle transmitted power of 20 watts) margins are positive in the case of the PM modes.

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The following is a summary of the major results:

1. The up-link margins are positive if 10 KW is transmitted by the MSFN station (85') to either the LM steerable or LM omni antenna; however, it is noted that the power margin of the up-voice and up-data channels using the LM omni antenna is only 0.8 dB in the worst case (full PM up-link mode and worst case parameters).

2. The down-link (using the LM steerable antenna, the MSFN (85') antenna, and a vehicle transmitted power of 20 watts) margins are positive in the case of the PM modes.

3. The down-link FM modes (using the steerable antenna and high RF power - 20 watts) provide positive margins for only the television and 1.6 kbps links (nominal conditions only).

4. The 1.6 kbps TLM, the down-link back-up voice and the ranging channels each have positive margins if each is transmitted by itself with 20 watts from the LM omni antenna to the MSFN station (85' antenna).

5. The negative margins shown in Table I, particularly in the FM television modes are not intended to imply complete loss of data. The voice/biomed channel for example has been demonstrated as a usable channel (with degraded intelligibility). For telemetry, the margins are related to a bit error rate of 10^{-6}. Negative margins indicate an error rate in excess of 10^{-6}. (For example, a margin of -2dB implies a bit error rate of 10^{-4}).

Conclusions

At lunar range, all of the PM modes of the LM operating with an 85-foot station of the MSFN can be expected to perform with positive power margin when using the LM steerable antenna even when operating under worst case conditions. When the LM configuration employs an omnidirectional antenna, low rate telemetry (1.6 kbps), back up voice or ranging can be supported when each is transmitted alone. Marginal but usable performance is exhibited when back-up voice and low rate telemetry are transmitted simultaneously from an LM omni antenna. The LM FM modes which include television all exhibit marginal or negative margins when transmitted from the LM steerable antenna to an MSFN 85-foot station. When operating in the FM modes, television should perform better than either the voice or telemetry channels. In the modes with television, it is expected that voice and low rate telemetry will be degraded but usable; the biomedical (back pack) telemetry which is transmitted via the voice channel will probably be lost.

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2034-NWS-ew

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References

1. R. L. Selden, "Apollo S-Band Communications Capabilities Using High Power RF Modes with Directional and Omnidirectional Antennas." TM 67-2034-3, April 26, 1967.

APPENDIX I

Purpose

The purpose of this appendix is to present more detailed results than those given in Table I and to present data that was used in the power margin calculations.

The system parameters which were used in this analysis are those contained in the NASA-MSC/ISD master parameter list dated March 12, 1968 and in the MSC Internal Note MSC-EB-R-67-1[1], "A Performance Analysis of the Apollo Unified S-Band Communications System for a Typical Lunar Mission", by D. G. Arndt, C. T. Dawson and R. W. Moorehead, dated May 2, 1967. Table A gives the power margins, Table B gives the threshold criteria, and Table C gives the received signal powers which can be expected using the LM-MSFN (85') link.

The results of the power margin calculations in Table A are listed with two decimal places to maintain a higher correlation between the results presented and the numerical output of the computer program used in this analysis. For further calculations using the results presented, the magnitudes of the power margins should be rounded off to one decimal place because this is the accuracy to which the system parameters are specified.

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[1]The required input signal to noise ratios for the FM modes were taken from this document.

TABLE I

POWER MARGINS AT LUNAR RANGE FOR THE LM-MSFN (85') COMMUNICATIONS LINK

	Service-Services Transmitted	LM Steerable Antenna LM Transmitting 20 Watts Nom. Case	LM Steerable Antenna LM Transmitting 20 Watts Worst Case	LM Steerable Antenna LM Transmitting .720 Watts Nom. Case	LM Steerable Antenna LM Transmitting .720 Watts Worst Case	LM Omni Antenna LM Transmitting 20 Watts Nom. Case	LM Omni Antenna LM Transmitting 20 Watts Worst Case
1.	(PM) Up Carrier - Full PM Mode* (MSFN Transmitting 10 kW)	36.3dB	32.2dB	36.3dB	32.2dB	17.5dB	13.4dB
2.	(PM) Up Voice or Up Data Full PM Mode* (MSFN Trans-Mitting 10 kW)	22.8	19.6	22.8	19.6	4.0	.8
3.	(PM) Down Carrier - Full PM Mode* w/51.2 KBPS TLM	38.8	34.4	21.7	18.0	16.1	12.0
4.	(PM) Down Voice w/Biomed Full PM Mode w/51.2 KBPS TLM	10.5	5.5	-6.7	-11.3		
5.	(PM) 51.2 KBPS TLM - Full PM Mode*	9.6	5.2	-7.5	-11.8		
6.	(PM) 1.6 KBPS TLM - Down Voice w/Biomed & 1.6 KBPS TLM	19.4	15.5	2.2	-1.00	-3.5	-7.2
7.	(PM) 1.6 KBPS TLM - Back Up Voice & 1.6 KBPS TLM	25.2	20.9	8.1	4.4	2.4	-1.7
8.	(PM) 1.6 KBPS TLM - TLM Only	27.5	22.8	10.4	6.4	4.7	.2

TABLE I (Continued)

POWER MARGINS AT LUNAR RANGE FOR THE LM-MSFN (85') COMMUNICATIONS LINK

Service-Services Transmitting	LM Steerable Antenna				LM Omni Antenna	
	LM Transmitting 20 Watts		LM Transmitting .720 Watts		LM Transmitting 20 Watts	
	Nom. Case	Worst Case	Nom. Case	Worst Case	Nom. Case	Worst Case
9. (PM) Down Back Up Voice - Voice Only	29.2dB	24.9dB	12.1dB	8.50dB	6.4dB	2.3dB
10. (PM) Ranging - Full PM Mode w/51.2 KBPS TLM	20.1	17.8	2.9	1.3		
11. (PM) Ranging- Ranging Only	38.0	34.1	20.8	17.6	15.2	11.5
12. (FM) 51.2 KBPS TLM - Full FM** Mode	-2.3	-8.5				
13. (FM) 1.6 KBPS TLM - Full FM** Mode	4.4	-1.5				
14. (FM) Down Voice w/Biomed - Full FM** Mode	-1.3	-7.3				
15. (FM) TV - Full FM** Mode	2.4	-2.1				

*A full PM mode is comprised of the simultaneous transmission of updata, upvoice and ranging in the case of the up-link and down-voice w/Biomed data, TLM and ranging in the case of the down-link.

**A full FM mode is comprised of the simultaneous transmission of down-voice w/Biomed data, TLM, and TV.

TABLE A (PM MODES)

POWER MARGINS AT LUNAR RANGE FOR THE
LM-MSFN (85') COMMUNICATIONS LINK

SERVICE	SERVICES TRANSMITTED	LM STEERABLE ANTENNA					LM OMNI ANTENNA			
		LM XMITTING 20W		LM XMITTING .72W			LM XMITTING 20W		LM XMITTING .72W	
		NOM. CASE	WORST CASE	NOM. CASE	WORST CASE		NOM. CASE	WORST CASE	NOM. CASE	WORST CASE
UP CARRIER	FULL MODE	36.31 dB	32.24 dB	36.31 dB	32.24 dB		17.51 dB	13.44 dB	17.51 dB	13.44 dB
"	UP VOICE & UP DATA, (NO RANGING)	36.11	32.04	36.11	32.04		17.31	13.24	17.31	13.24
"	UP VOICE OR UP DATA ONLY	31.68	27.61	31.68	27.61		12.88	8.81	12.88	8.81
UP VOICE OR UP DATA	FULL MODE[1]	22.81	19.59	22.81	19.59		4.01	.79	4.01	.79
"	UP VOICE & UP DATA (NO RANGING)	24.42	21.29	24.42	21.29		5.62	2.49	5.62	2.49
"	UP VOICE OR UPDATA ONLY	29.12	25.98	29.12	25.98		10.32	7.18	10.32	7.18
DOWN CARRIER	FULL MODE WITH 51.2 KBPS TLM	38.80	34.38	21.66	17.95		16.13	12.02	-1.01	-4.41
"	DOWN VOICE W/BIOMED & 51.2 KBPS TLM	39.68	35.77	22.54	19.34		16.88	13.17	-.26	-3.26
"	DOWN VOICE W/BIOMED & 1.6 KBPS TLM	40.43	36.53	23.30	20.10		17.63	13.93	.50	-2.50
"	1.6 KBPS TLM ONLY	41.53	38.86	24.40	22.43		18.73	16.26	1.59	-.17
"	DOWN VOICE W/BIOMED ONLY	41.53	37.63	24.40	21.20		18.73	15.03	1.60	-1.40
"	DOWN BACK UP VOICE & 1.6 KBPS TLM	40.23	36.33	23.10	19.90		17.43	13.73	.30	-2.70
"	DOWN BACK UP VOICE ONLY	44.37	40.47	27.24	24.04		21.57	17.87	4.44	1.44
"	RANGING ONLY	44.79	40.89	27.66	24.46		21.99	18.29	4.86	1.86
DOWN VOICE W/BIOMED	FULL MODE WITH 51.2 KBPS TLM	10.49	5.47	-6.65	-11.27		-12.81	-18.13	-30.51	-34.66
"	DOWN VOICE W/BIOMED & 51.2 KBPS TLM	11.37	6.87	-5.77	-9.57		-11.83	-16.63	-29.64	-33.24
"	DOWN VOICE W/BIOMED & 1.6 KBPS TLM	16.67	12.18	-.47	-4.25		-6.13	-10.62	-24.32	-27.91
51.2 KBPS TLM	FULL MODE	9.63	5.20	-7.51	-11.76		-13.94	-18.48	-31.40	-34.95
"	DOWN VOICE W/BIOMED & 51.2 KBPS TLM	10.51	6.60	-6.63	-10.12		-12.97	-16.99	-30.51	-33.51
1.6 KBPS TLM	DOWN VOICE W/BIOMED & 1.6 KBPS TLM	19.35	15.45	2.22	-.98		-3.45	-7.15	-21.64	-24.64
"	1.6 KBPS TLM ONLY	27.53	22.78	10.39	6.35		4.73	.18	-13.19	-17.27
"	1.6 KBPS TLM & BACK UP VOICE	25.19	20.87	8.06	4.44		2.39	-1.73	-14.74	-18.16
DOWN BACK UP VOICE	DOWN BACK UP VOICE ONLY	29.22	24.90	12.09	8.47		6.42	2.30	-10.71	-14.13
"	DOWN BACK UP VOICE & 1.6 KBPS TLM	25.06	20.75	7.93	4.32		2.26	-1.85	-14.87	-17.28
RANGING	FULL MODE WITH 51.2 KBPS TLM	20.05	17.76	2.91	1.33		-6.55	-10.69	-23.69	-27.12
"	RANGING ONLY	37.96	34.06	20.83	17.63		15.16	11.46	-1.97	-4.97

TABLE B

Threshold Criteria Used in Power Margin Calculations

	Service	Minimum Req. S/N in Bandwidth Nom.Case	Worst Case	Nom. Case	Worst Case	Minimum Req. Performance
		(in dB)		(in Hz)		
1.	Up Carrier	12		1100.	1500	
2.	Up Voice and Up Data	10		22,000.	24200.	
3.	Down Carrier	12		50.		
4.	Down Voice w/ Bio-Med DATA (PM)	8		$42.x10^3$	$48.x10^3$	
5.	51.2 KBPS TLM (PM)	7		$1.8x10^5$		Bit Error Rate of 10^{-6}
6.	1.6 KBPS TLM (PM)	5.9		7250		Bit Error Rate of 10^{-6}
7.	Down Back-Up Voice (PM)	4.0		2840	3124	70% Word Intelligibility
8.	Ranging	32		1		Range Code Acquisition Time of 60 Seconds
9.	TV (FM)	5.5	6.1		$4.8x10^6$	
10.	Down Voice w/ Bio-med Data (FM)	9.2	11.3		$4.8x10^6$	
11.	51.2 KBPS TLM (FM)	10.2	12.5		$4.8x10^6$	
12.	1.6 KBPS TLM (FM)	3.5	5.5		$4.8x10^6$	

TABLE C

Received Signal Powers for LM-MSFN (85') Link

Up Link - MSFN (85') Transmitting 10k Watts		
LM Receiving Antenna	Nominal Case	Worst Case
Steerable	-108.80 dBW	-111.52 dBW
Omni	-127.60 dBW	-130.32 dBW
Down Link - LM Transmitting 20 Watts		
LM Transmitting Antenna	Nominal Case	Worst Case
Steerable	-130.71 dBW	-134.61 dBW
Omni	-153.51 dBW	-157.21 dBW
Down Link - LM Transmitting .720 Watts		
LM Transmitting Antenna	Nominal Case	Worst Case
Steerable	-147.84 dBW	-151.04 dBW
Omni	-170.64 dBW	-173.64 dBW

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